

Windows 2000

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- Design Principles
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- File system
- Networking
- Programmer Interface

21.1

Windows 2000

- 32-bit preemptive multitasking operating system for Intel microprocessors.
- Key goals for the system:
 - ☞ portability
 - ☞ security
 - ☞ POSIX compliance
 - ☞ multiprocessor support
 - ☞ extensibility
 - ☞ international support
 - ☞ compatibility with MS-DOS and MS-Windows applications.
- Uses a micro-kernel architecture.
- Available in four versions, Professional, Server, Advanced Server, National Server.

21.2

History

- In 1988, Microsoft decided to develop a “new technology” (NT) portable operating system that supported both the OS/2 and POSIX APIs.
- Originally, NT was supposed to use the OS/2 API as its native environment but during development NT was changed to use the Win32 API, reflecting the popularity of Windows 3.0.

21.3

Design Principles

- Extensibility — layered architecture.
 - ☞ Executive, which runs in protected mode, provides the basic system services.
 - ☞ On top of the executive, several server subsystems operate in user mode.
 - ☞ Modular structure allows additional environmental subsystems to be added without affecting the executive.
- Portability — 2000 can be moved from one hardware architecture to another with relatively few changes.
 - ☞ Written in C and C++.
 - ☞ Processor-dependent code is isolated in a dynamic link library (DLL) called the “hardware abstraction layer” (HAL).

21.4

Design Principles (Cont.)

- Reliability — 2000 uses hardware protection for virtual memory, and software protection mechanisms for operating system resources.
- Compatibility — applications that follow the IEEE 1003.1 (POSIX) standard can be compiled to run on 2000 without changing the source code.
- Performance — 2000 subsystems can communicate with one another via high-performance message passing.
 - ☞ Preemption of low priority threads enables the system to respond quickly to external events.
 - ☞ Designed for symmetrical multiprocessing.
- International support — supports different locales via the national language support (NLS) API.

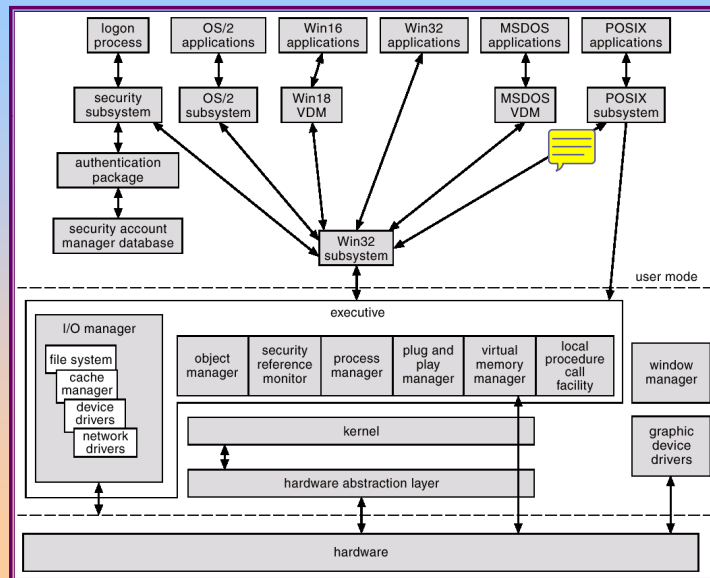
21.5

2000 Architecture

- Layered system of modules.
- Protected mode — HAL, kernel, executive.
- User mode — collection of subsystems
 - ☞ Environmental subsystems emulate different operating systems.
 - ☞ Protection subsystems provide security functions.

21.6

Depiction of 2000 Architecture



21.7

System Components — Kernel

- Foundation for the executive and the subsystems.
- Never paged out of memory; execution is never preempted.
- Four main responsibilities:
 - ☞ thread scheduling
 - ☞ interrupt and exception handling
 - ☞ low-level processor synchronization
 - ☞ recovery after a power failure
- Kernel is object-oriented, uses two sets of objects.
 - ☞ *dispatcher* objects control dispatching and synchronization (events, semaphores, threads and timers).
 - ☞ *control* objects (asynchronous procedure calls, interrupts, power notify, power status, process and profile objects.)

21.8

Kernel — Process and Threads

- The process has a virtual memory address space, information (such as a base priority), and an affinity for one or more processors.
- Threads are the unit of execution scheduled by the kernel's dispatcher.
- Each thread has its own state, including a priority, processor affinity, and accounting information.
- A thread can be one of six states: ready, standby, running, waiting, transition, and terminated.

21.9

Kernel — Scheduling

- The dispatcher uses a 32-level priority scheme to determine the order of thread execution. Priorities are divided into two classes..
 - ☞ The real-time class contains threads with priorities ranging from 16 to 32.
 - ☞ The variable class contains threads having priorities from 0 to 15.
- Characteristics of 2000's priority strategy.
 - ☞ Trends to give very good response times to interactive threads that are using the mouse and windows.
 - ☞ Enables I/O-bound threads to keep the I/O devices busy.
 - ☞ Complete-bound threads soak up the spare CPU cycles in the background.

21.10

Kernel — Scheduling (Cont.)

- Scheduling can occur when a thread enters the ready or wait state, when a thread terminates, or when an application changes a thread's priority or processor affinity.
- Real-time threads are given preferential access to the CPU; but 2000 does not guarantee that a real-time thread will start to execute within any particular time limit.

21.11

Kernel — Trap Handling

- The kernel provides trap handling when exceptions and interrupts are generated by hardware or software.
- Exceptions that cannot be handled by the trap handler are handled by the kernel's *exception dispatcher*.
- The interrupt dispatcher in the kernel handles interrupts by calling either an interrupt service routine (such as in a device driver) or an internal kernel routine.
- The kernel uses spin locks that reside in global memory to achieve multiprocessor mutual exclusion.

21.12

Executive — Object Manager

- 2000 uses objects for all its services and entities; the object manager supervises the use of all the objects.
 - ✎ Generates an object *handle*
 - ✎ Checks security.
 - ✎ Keeps track of which processes are using each object.
- Objects are manipulated by a standard set of methods, namely *create*, *open*, *close*, *delete*, *query name*, *parse* and *security*.

21.13

Executive — Naming Objects

- The 2000 executive allows any object to be given a name, which may be either permanent or temporary.
- Object names are structured like file path names in MS-DOS and UNIX.
- 2000 implements a *symbolic link object*, which is similar to *symbolic links* in UNIX that allow multiple nicknames or aliases to refer to the same file.
- A process gets an object handle by creating an object by opening an existing one, by receiving a duplicated handle from another process, or by inheriting a handle from a parent process.
- Each object is protected by an access control list.

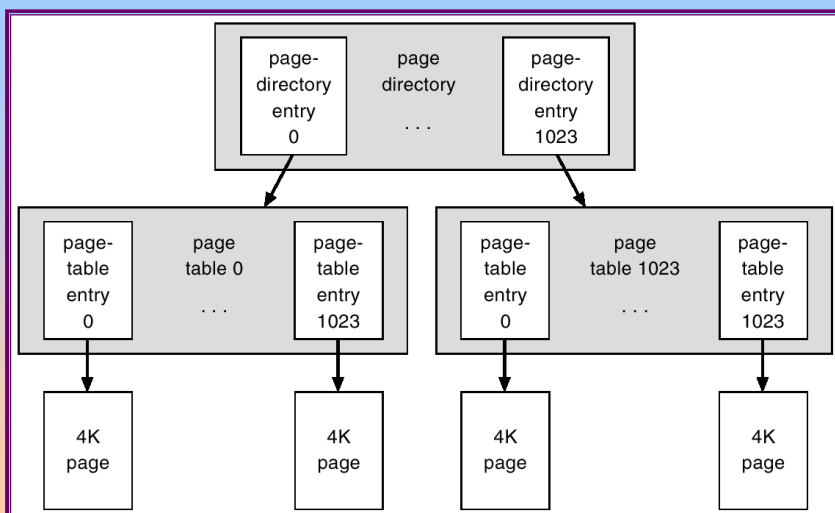
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Executive — Virtual Memory Manager

- The design of the VM manager assumes that the underlying hardware supports virtual to physical mapping a paging mechanism, transparent cache coherence on multiprocessor systems, and virtual addressing aliasing.
- The VM manager in 2000 uses a page-based management scheme with a page size of 4 KB.
- The 2000 VM manager uses a two step process to allocate memory.
 - ☞ The first step reserves a portion of the process's address space.
 - ☞ The second step commits the allocation by assigning space in the 2000 paging file.

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Virtual-Memory Layout



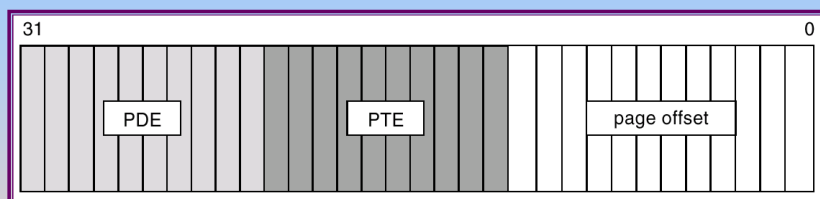
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Virtual Memory Manager (Cont.)

- The virtual address translation in 2000 uses several data structures.
 - ☞ Each process has a *page directory* that contains 1024 *page directory entries* of size 4 bytes.
 - ☞ Each page directory entry points to a *page table* which contains 1024 *page table entries* (PTEs) of size 4 bytes.
 - ☞ Each PTE points to a 4 KB *page frame* in physical memory.
- A 10-bit integer can represent all the values from 0 to 1023, therefore, can select any entry in the page directory, or in a page table.
- This property is used when translating a virtual address pointer to a byte address in physical memory.
- A page can be in one of six states: valid, zeroed, free standby, modified and bad.

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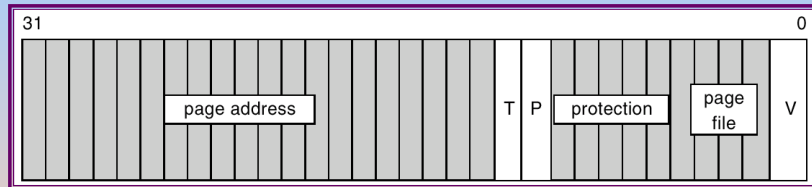
Virtual-to-Physical Address Translation



- 10 bits for page directory entry, 10 bits for page table entry, and 12 bits for byte offset in page.

21.18

Page File Page-Table Entry



- 5 bits for page protection, 20 bits for page frame address, 4 bits to select a paging file, and 3 bits that describe the page state. $V = 0$

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Executive — Process Manager

- Provides services for creating, deleting, and using threads and processes.
- Issues such as parent/child relationships or process hierarchies are left to the particular environmental subsystem that owns the process.

21.20

Executive — Local Procedure Call Facility

- The LPC passes requests and results between client and server processes within a single machine.
- In particular, it is used to request services from the various 2000 subsystems.
- When a LPC channel is created, one of three types of message passing techniques must be specified.
 - ☞ First type is suitable for small messages, up to 256 bytes; port's message queue is used as intermediate storage, and the messages are copied from one process to the other.
 - ☞ Second type avoids copying large messages by pointing to a shared memory section object created for the channel.
 - ☞ Third method, called *quick* LPC was used by graphical display portions of the Win32 subsystem.

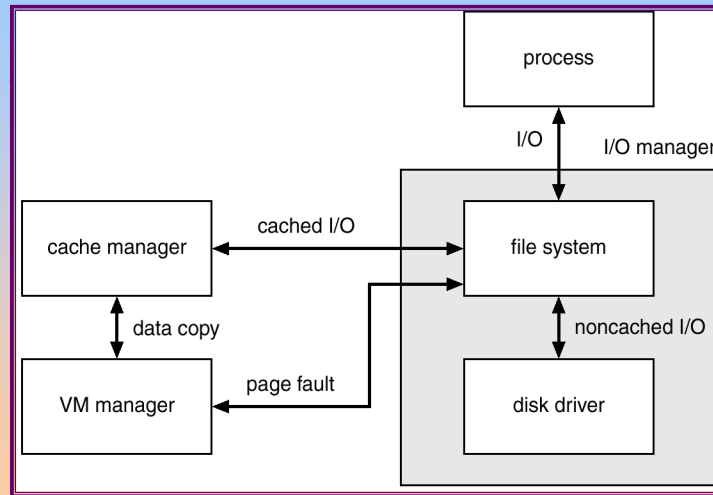
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Executive — I/O Manager

- The I/O manager is responsible for
 - ☞ file systems
 - ☞ cache management
 - ☞ device drivers
 - ☞ network drivers
- Keeps track of which installable file systems are loaded, and manages buffers for I/O requests.
- Works with VM Manager to provide memory-mapped file I/O.
- Controls the 2000 cache manager, which handles caching for the entire I/O system.
- Supports both synchronous and asynchronous operations, provides time outs for drivers, and has mechanisms for one driver to call another.

21.22

File I/O



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Executive — Security Reference Manager

- The object-oriented nature of 2000 enables the use of a uniform mechanism to perform runtime access validation and audit checks for every entity in the system.
- Whenever a process opens a handle to an object, the security reference monitor checks the process's security token and the object's access control list to see whether the process has the necessary rights.

21.24

Environmental Subsystems

- User-mode processes layered over the native 2000 executive services to enable 2000 to run programs developed for other operating system.
- 2000 uses the Win32 subsystem as the main operating environment; Win32 is used to start all processes. It also provides all the keyboard, mouse and graphical display capabilities.
- MS-DOS environment is provided by a Win32 application called the *virtual dos machine* (VDM), a user-mode process that is paged and dispatched like any other 2000 thread.

21.25

Environmental Subsystems (Cont.)

- 16-Bit Windows Environment:
 - ☞ Provided by a VDM that incorporates *Windows on Windows*.
 - ☞ Provides the Windows 3.1 kernel routines and sub routines for window manager and GDI functions.
- The POSIX subsystem is designed to run POSIX applications following the POSIX.1 standard which is based on the UNIX model.

21.26

File System

- The fundamental structure of the NTFS file system (NTFS) is a *volume*.
 - ✎ Created by the NTFS disk administrator utility.
 - ✎ Based on a logical disk partition.
 - ✎ May occupy a portions of a disk, an entire disk, or span across several disks.
- All *metadata*, such as information about the volume, is stored in a regular file.
- NTFS uses *clusters* as the underlying unit of disk allocation.
 - ✎ A cluster is a number of disk sectors that is a power of two.
 - ✎ Because the cluster size is smaller than for the 16-bit FAT file system, the amount of internal fragmentation is reduced.

21.27

File System — Internal Layout

- NTFS uses *logical cluster numbers* (LCNs) as disk addresses.
- A file in NTFS is not a simple byte stream, as in MS-DOS or UNIX, rather, it is a structured object consisting of *attributes*.
- Every file in NTFS is described by one or more records in an array stored in a special file called the Master File Table (MFT).
- Each file on an NTFS volume has a unique ID called a *file reference*.
 - ✎ 64-bit quantity that consists of a 48-bit file number and a 16-bit sequence number.
 - ✎ Can be used to perform internal consistency checks.
- The NTFS name space is organized by a hierarchy of directories; the *index root* contains the top level of the B+ tree.

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File System — Recovery

- All file system data structure updates are performed inside transactions.
 - ✎ Before a data structure is altered, the transaction writes a log record that contains redo and undo information.
 - ✎ After the data structure has been changed, a commit record is written to the log to signify that the transaction succeeded.
 - ✎ After a crash, the file system data structures can be restored to a consistent state by processing the log records.

21.29

File System — Recovery (Cont.)

- This scheme does not guarantee that all the user file data can be recovered after a crash, just that the file system data structures (the metadata files) are undamaged and reflect some consistent state prior to the crash..
- The log is stored in the third metadata file at the beginning of the volume.
- The logging functionality is provided by the 2000 *log file service*.

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File System — Security

- Security of an NTFS volume is derived from the 2000 object model.
- Each file object has a security descriptor attribute stored in this MFT record.
- This attribute contains the access token of the owner of the file, and an access control list that states the access privileges that are granted to each user that has access to the file.

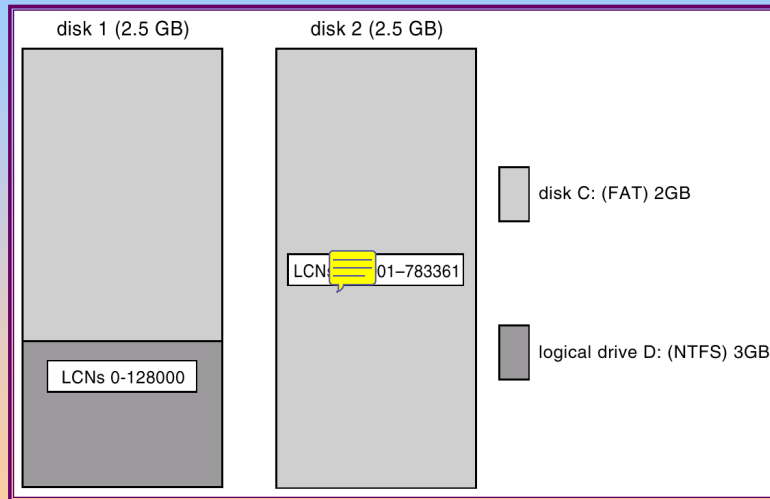
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Volume Management and Fault Tolerance

- F_tD

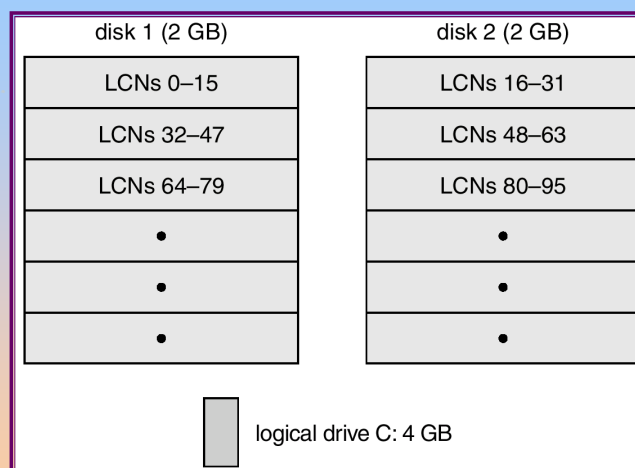
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Volume Set On Two Drives



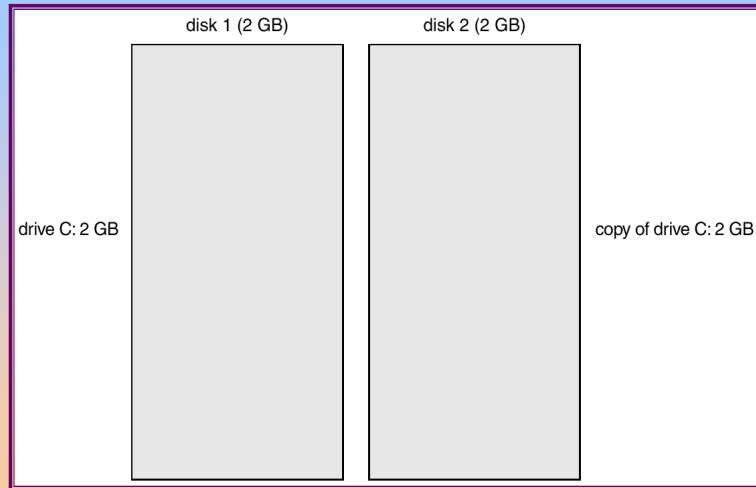
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Stripe Set on Two Drives



21.34

Mirror Set on Two Drives



21.35

File System — Compression

- To compress a file, NTFS divides the file's data into *compression units*, which are blocks of 16 contiguous clusters.
- For sparse files, NTFS uses another technique to save space.
 - ☞ Clusters that contain all zeros are not actually allocated or stored on disk.
 - ☞ Instead, gaps are left in the sequence of virtual cluster numbers stored in the MFT entry for the file.
 - ☞ When reading a file, if a gap in the virtual cluster numbers is found, NTFS just zero-fills that portion of the caller's buffer.

21.36

Networking

- 2000 supports both peer-to-peer and client/server networking; it also has facilities for network management.
- To describe networking in 2000, we refer to two of the internal networking interfaces:
 - ✦ NDIS (Network Device Interface Specification) — Separates network adapters from the transport protocols so that either can be changed without affecting the other.
 - ✦ TDI (Transport Driver Interface) — Enables any session layer component to use any available transport mechanism.
- 2000 implements transport protocols as drivers that can be loaded and unloaded from the system dynamically.

21.37

Networking — Protocols

- The server message block (SMB) protocol is used to send I/O requests over the network. It has four message types:
 - Session control
 - File
 - Printer
 - Message
- The network basic Input/Output system (NetBIOS) is a hardware abstraction interface for networks. Used to:
 - ✦ Establish logical names on the network.
 - ✦ Establish logical connections of sessions between two logical names on the network.
 - ✦ Support reliable data transfer for a session via NetBIOS requests or *SMBs*

21.38

Networking — Protocols (Cont.)

- NetBEUI (NetBIOS Extended User Interface): default protocol for Windows 95 peer networking and Windows for Workgroups; used when 2000 wants to share resources with these networks.
- 2000 uses the TCP/IP Internet protocol to connect to a wide variety of operating systems and hardware platforms.
- PPTP (Point-to-Point Tunneling Protocol) is used to communicate between Remote Access Server modules running on 2000 machines that are connected over the Internet.
- The 2000 NWLink protocol connects the NetBIOS to Novell NetWare networks.

21.39

Networking — Protocols (Cont.)

- The Data Link Control protocol (DLC) is used to access IBM mainframes and HP printers that are directly connected to the network.
- 2000 systems can communicate with Macintosh computers via the Apple Talk protocol if an 2000 Server on the network is running the Windows 2000 Services for Macintosh package.

21.40

Networking — Dist. Processing Mechanisms

- 2000 supports distributed applications via named NetBIOS, named pipes and mailslots, Windows Sockets, Remote Procedure Calls (RPC), and Network Dynamic Data Exchange (NetDDE).
- NetBIOS applications can communicate over the network using NetBEUI, NWLink, or TCP/IP.
- Named pipes are connection-oriented messaging mechanism that are named via the *uniform naming convention* (UNC).
- Mailslots are a connectionless messaging mechanism that are used for broadcast applications, such as for finding components on the network,
- Winsock, the windows sockets API, is a session-layer interface that provides a standardized interface to many transport protocols that may have different addressing schemes.

21.41

Distributed Processing Mechanisms (Cont.)

- The 2000 RPC mechanism follows the widely-used Distributed Computing Environment standard for RPC messages, so programs written to use 2000 RPCs are very portable.
 - ☞ RPC messages are sent using NetBIOS, or Winsock on TCP/IP networks, or named pipes on LAN Manager networks.
 - ☞ 2000 provides the Microsoft *Interface Definition Language* to describe the remote procedure names, arguments, and results.

21.42

Networking — Redirectors and Servers

- In 2000, an application can use the 2000 I/O API to access files from a remote computer as if they were local, provided that the remote computer is running an MS-NET server.
- A *redirector* is the client-side object that forwards I/O requests to remote files, where they are satisfied by a server.
- For performance and security, the redirectors and servers run in kernel mode.

21.43

Access to a Remote File

- The application calls the I/O manager to request that a file be opened (we assume that the file name is in the standard UNC format).
- The I/O manager builds an I/O request packet.
- The I/O manager recognizes that the access is for a remote file, and calls a driver called a Multiple Universal Naming Convention Provider (MUP).
- The MUP sends the I/O request packet asynchronously to all registered redirectors.
- A redirector that can satisfy the request responds to the MUP.
 - ☞ To avoid asking all the redirectors the same question in the future, the MUP uses a cache to remember with redirector can handle this file.

21.44

Access to a Remote File (Cont.)

- The redirector sends the network request to the remote system.
- The remote system network drivers receive the request and pass it to the server driver.
- The server driver hands the request to the proper local file system driver.
- The proper device driver is called to access the data.
- The results are returned to the server driver, which sends the data back to the requesting redirector.

21.45

Networking — Domains

- NT uses the concept of a domain to manage global access rights within groups.
- A domain is a group of machines running NT server that share a common security policy and user database.
- 2000 provides three models of setting up trust relationships.
 - ☞ *One way, A trusts B*
 - ☞ *Two way, transitive, A trusts B, B trusts C so A, B, C trust each other*
 - ☞ *Crosslink – allows authentication to bypass hierarchy to cut down on authentication traffic.*


21.46

Name Resolution in TCP/IP Networks

- On an IP network, name resolution is the process of converting a computer name to an IP address.

e.g., `www.bell-labs.com` resolves to `135.104.1.14`

- 2000 provides several methods of name resolution:

- ✎ Windows Internet Name Service (WINS)
- ✎ broadcast name resolution
- ✎ domain name system (DNS)
- ✎ a host file
- ✎ an LMHOSTS 

21.47

Name Resolution (Cont.)

- WINS consists of two or more WINS servers that maintain a dynamic database of name to IP address bindings, and client software to query the servers.
- WINS uses the Dynamic Host Configuration Protocol (DHCP), which automatically updates address configurations in the WINS database, without user or administrator intervention.

21.48